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Preliminary Study of Tree Plantations in Oklahoma: Relative Survival by Species, and Factors Affecting Survival

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A PRELIMINARY STUDY OF TREE PLANTATIONS IN OKLAHOMA: RELATIVE SURVIVAL BY SPECIES, AND FACTORS AFFECTING SURVIVAL

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Thousands of forest plantations have been established in Oklahoma. Many of them have failed completely. Others, though still in existence, are hardly worth the effort expended in their establishment. The loss in time and money due to planting trees which fail to grow into usefulness is considerable. Therefore the Experiment Station undertook to analyze the causes of failures and unsatisfactory growth, as a means of providing information which would help reduce this loss in the future. This bulletin reports the results of that analysis.

Practical suggestions resulting from this study are summarized in Okla. Agri. Exp. Sta. Bul. B-314, **Trees and Tree Planting for Posts, Windbreaks, and Erosion Control,** prepared for farmers and landowners interested in setting out their own windbreaks or post lots. The following more detailed report of the study was prepared for foresters and others who might want additional information.

Methods

The tree plantings inspected in the course of this study are believed to be fairly representative of all plantations in the state.

The original selection of 500 plantations was made from the files of the State Division of Forestry. These plantations are located in 16 counties of the state as shown in Fig. 1. They contained not less than 1,000 trees each and at the time of study none was less than 3 years of age.

The owners of the selected plantations were sent a questionnaire pertaining to various features of the plantations. One hundred and twenty-five replied. It is recognized that the plantations for which the information

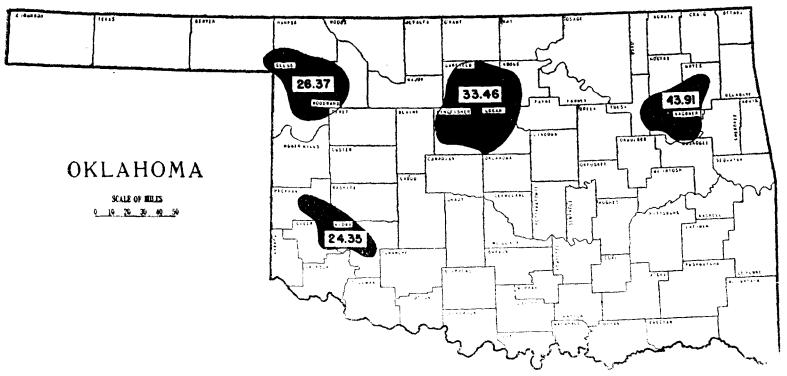

Fig. 1.—Map of Oklahoma, showing four areas in which the study was made. The figures represent average annual precipitation for nine years, 1936-1944 inclusive.

was received by mail were in some respects not representative. Owners who either had lost their plantations or were generally unsatisfied with them failed to reply. Consequently, data pertaining to absolute survival and growth, and information on aftercare of the plantations, present a picture much brighter than it actually is. On the other hand, **relative** survival and **relative** rates of growth of various species may be considered as applicable to most plantations within the state. This conclusion has been substantiated by the results of personal examination of these and other plantations in Oklahoma.

The attempt to secure preliminary information by mail was followed by actual examination of plantations within designated areas (Fig. 1). These examinations covered chiefly plantations originally chosen from the files of the State Division of Forestry. However, in the western half of the state many, if not most, of the plantations are shelterbelts planted with the assistance of or by the United States Forest Service; and some of these were also included in the survey.

Information gathered during examination in the field included average survival, height and diameter of trees, spacing and arrangement of species, topography and exposure of the site, and care of the plantation. Notes were also taken on apparent injuries by insects and diseases.

Due to extremely variable conditions under which the trees were planted and have been growing (season of the year, precipitation, soil, topography, exposure, competition, etc.) it is impossible to analyze the data statistically except in the case of individual mixed plantings. Even in many of these, the soil, the topography and exposure are so variable that each plantation must be broken into small parts and each part handled separately to get statistically significant results.

The following discussion and the results of the inspection are based on field data and observations without necessarily attempting to bring together or averaging the figures for the same species or similar sites.

Because of the existence of marked variations in ecological conditions in different parts of the state, the results of this study, pertaining to the behavior of individual species, are presented separately for different sections of Oklahoma.

Effect of Precipitation on the Survival of Trees

It is often assumed that survival of trees planted in the field is strongly correlated with the average amount of annual precipitation. The present study indicates, however, that except for a few individual cases of heavy loss directly attributable to severe droughts, total precipitation alone is not of such great importance as is commonly assumed, at least for species generally planted in Oklahoma. Table I, based on species found in at least 10 plantations in any one precipitation zone (east, 44 inches; central, 33 inches; west, 25 inches) shows that total annual precipitation is seldom the limiting factor in the survival of trees. For instance, red cedar survived better in the west (average 73 percent) where average annual precipitation during the existence of the plantations under study was 25.33 inches, than in the north central part of the state (64 percent), which received an average precipitation of 33.46 inches. Survival of catalpa in the 33.46 inches precipitation zone was 96 percent, while in the 43.91 inches zone it was only 84 percent. Mulberry in the western zone survived to the same extent as in the north central part of the state; and survival of black locust in the eastern zone was 80 percent as against 88 percent in the western zone.

TABLE I.—Survival of Individual Species in Various Precipitation Zones in Oklahoma.

Species	Survival by Precipitation Zones (Percent) *			
	Northeast 43.91 in.	North Central 33.46 in.	Northwest 26.37 in.	Southwest 24.35 in.
Red Cedar	24	64	71	75
Black Walnut	1	40	90	32
Chinese Elm	51	84	89	76
American Elm		85		
Green Ash	95	95	89	70
Catalpa	84	96	93	85
Honey Locust	--	98	83	81
Hackberry	--	55	29	73
Osage Orange	95	85	81	75
Mulberry	78	76**	84	67
Black Locust	80	87	88	89
Pine (spp.)	0	7	38	2
Cottonwood	--	--	72	86

* Average annual precipitation for nine years (1936-1944, inclusive).
** Includes one plantation completely lost.

Since no correlation was found between average annual precipatation and the survival of trees, it is suggested that so far as moisture is concerned the critical factor may be the moisture conditions at time of planting. No statistical information is available on the relationship between available moisture at time of planting and survival of trees. However, experience in Station plantings, particularly of conifers, indicates that weather and soil moisture conditions at the time of planting have a pronounced effect on subsequent survival of trees. A tree once established is able to withstand prolonged periods of dry weather. Shortage of moisture can easily be a critical factor immediately after planting, when soil is freshly disturbed and roots are dormant and have been heavily trimmed.

Effect of Soil Texture on the Survival of Trees

While climate is recognized as important, the results of this study point to soil factors as having particularly decisive influence on growth and survival of trees in Oklahoma plantations. This fact is well illustrated by pronounced differences in the survival and rate of growth of a single species on different soils.

The most reliable and practical indicator of soils unsuitable for tree growth was high clay content (20 percent plus).

A total of 72 soil samples was analyzed for N, P, K, pH, and percentages of sand, silt and clay. Of these factors only one, high clay content, appeared to be a possible practical indicator of the ability of soil to maintain tree growth.

Some soils with less than 1 ppm. of either N, P or K maintained good vigorous plantations, while presence of these elements in large amounts did not necessarily correlate with good or even fair growth.

pH of soil samples ranged from a low of 4.9 to a high of 8.8 without showing marked effect on the behavior of trees. Even such species as black locust did well on soil of pH of 4.9 (very acid) when other factors appeared to be favorable.

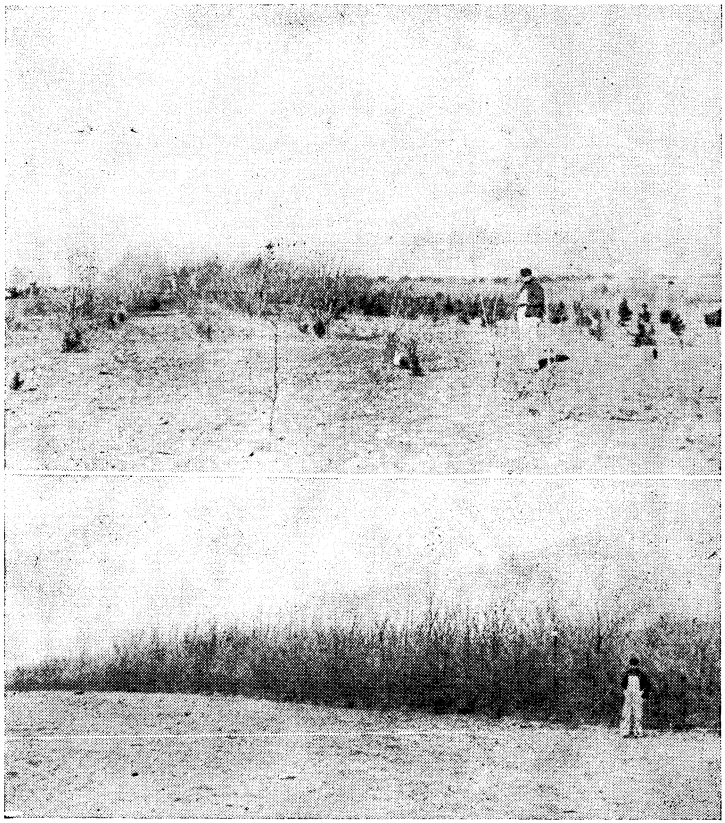

Fig. 2.—Six-year old shelterbelt in Greer County. At top is its middle section; at bottom is the west half of the shelterbelt. Variation in soil is responsible for the difference in the survival and vigor of trees. The entire shelterbelt was planted on the same day and to the same species.

Similar lack of constant relationship was noted between the color of the soil and the site quality, although generally a large number of light-colored soils appear to fall into a low productivity class. One typically unfavorable sign in the appearance of soils was mottling. Presence of mottling within a depth of 36 inches invariably indicated a site of poor quality.

In 18 cases of poor growth, 17 were found on soils containing 20 percent or more clay within three feet of the soil surface (Table II). On the other hand, in 15 cases of good growth, 10 were located on soils with less than 20 percent clay. Thus, in 22 instances of soil containing 20 percent or more clay, 17 resulted in poor growth.

TABLE II.—Good and Poor Growth as Related to Clay Content of Soil.

Growth quality	Number of plantings having indicated percentage of clay in top 36 inches of soil		
	Less than 20%	20%-25%	26% or more
Poor	1	6	11
Good	10	1	4

Light soil is not an assurance of high quality of the planting site, however. Excessive drainage on sandy soil is believed to be the cause of poor growth in one of the plantations studied. This soil had 96 percent sand in the top 45 inches.

Of five good quality plantations growing on heavy soils (20 percent clay), three are what may be called border-line cases. In one of these the amount of clay is 22 percent; in two others 26 percent clay was found at a depth of 33 inches, while at the depth of between 18 inches and 24 inches the percentages of clay were respectively 12 percent and 16 percent. This, together with the composition of the two last plantations (Chinese elm, catalpa and black locust), explains the presence of good growth on relatively shallow soils underlaid with heavy subsoil. It should be pointed out also that two plantations under discussion are located in the average annual precipitation zone of approximately 35 inches.

The fourth good quality plantation on heavy soil (36 percent clay at the depth of 6 inches) is located on low land with the probability of a shallow water table and the presence of a continuously available moisture supply in the upper layer of the soil.

In the fifth case the clay content is 20 percent at a depth of 6 inches and 40 percent at 18 inches. Presence of gravel in the soil might have been responsible for the successful establishment of this plantation.

Discussion of Species by Areas

NORTH CENTRAL OKLAHOMA

The North Central part of Oklahoma receives an average of 30 to 35 inches of precipitation annually and has a growing season of approximately 215 days. The soils are less variable than in other parts of the state. They belong to the central and western prairies, with some sand hills along the Cimarron River and its tributaries.

A considerable proportion of this area in the State bears natural forests varying from the blackjack post oak type on the upland to a mixture of elms, ash, hackberry, pecan, cottonwood and other typical bottomland species along the streams.

Red Cedar.

Of 28 plantations examined, 14 contained red cedar and one other is listed as having had this species in its original planting. Of the 14, six still have between 80 percent and 98 percent of the original red cedar trees. In three other plantations it was impossible to determine the survival because the trees were scattered unevenly over a large area, and in the remaining five the survival ranged from 10 percent to 70 percent.

High mortality of red cedar in some plantations was due to such causes as prolonged periods of inundation after rains, very keen competition with fast-growing hardwoods (60 percent mortality), and gen-

erally poor site exposed to hot winds and sand blowing (mortality 90 percent). In the latter case other species in the same plantation have done very poorly also.

Unusually severe droughts of 1934 and 1936 were responsible for complete loss of red cedar in one plantation. In another instance a 50 percent loss was attributed by the owner to freezing in transit.

The rate of growth of red cedar in comparison with that of other species has been slow. On the average, up to seven years of age the height of this species in feet is equal to the number of years the trees have been in the field. The tallest trees observed were 12 feet tall after seven years in the field. These were located on low, fertile land.

American Elm.

American elm was found in two of the best plantations examined. The first is a field shelterbelt located on a bottomland site of very good quality. Here survival of American elm was 70 percent, lower than that of any other species (except pine) in the plantation. This relatively low survival might have been due either to excessive competition on the part of weeds which cover the plantation in profusion, or to the injury by rabbits. American elm forms the outside row in the plantation.

In the other plantation (windbreak) American elm survived 100 percent even though located between two such fast growing species as Chinese elm and honey locust. In the rate of growth (8 feet in 4 years) it was poorer than Chinese elm, honey locust and mulberry, but superior to green ash and hackberry.

Black Locust.

Black locust has not been planted very extensively in north central Oklahoma. One row found in a shelterbelt is the only planting permitting direct comparison with other species growing on the same site. In this particular location (low land adjacent to a creek) black locust has done very well both in survival (100 percent) and growth. It forms the tallest row (average height 18 feet), surpassing in height even the Chinese elm (height 16 feet) and honey locust (height 12 feet). Having on one side a row of hackberry with its characteristic "lower-than-average" survival, black locust has had an opportunity to spread by suckering and now fills up many openings created by loss of hackberry. Abundance of tall weeds and generally a thick, vigorous growth of all trees suggests a site of rather exceptional quality.

Two other plantations of black locust were pure, yet immediately adjacent to pure stands of other species on the lower ground. One of these, on terraced ground (thin, somewhat eroded soil) suffered a considerable loss (40 percent), partly because of unfavorable site and partly from injury by rabbits. The latter cause was probably responsible also for a rather extensive suckering of black locust. The age of this planting at the time of inspection was 4 years; the average height of black locust was 10 feet, though individual trees (probably those which avoided injury by rabbits) were as high as 18 feet. A Chinese elm plantation adjoining black locust on the lower land (planted same year) was on the average 20 feet high with a survival of 90 percent.

The largest planting of black locust inspected during this study is located on the top of a hill on sandy, well drained soil. At the time of examination it was 6 years old and appeared to have been well kept. At that age the trees reached an average height of 20 feet and an average diameter at base of 3 inches.

Fig. 3.—Pure black locust plantation (Logan County). Age six years. Average height 20 feet. Survival 98 percent. Spacing 3 x 10 feet and 6 x 10 feet.

Black Walnut.

Observations on black walnut in north central Oklahoma were obtained from only three plantations, with a total of 350 trees of this species.

All three plantings were made in 1938. The largest (200 trees) is located on fairly low land and a reasonably fair soil. However, even here survival seven years after planting was only 60 percent. Under these conditions, trees have reached 7 feet in height and 2½ inches in dbh. In two other plantations, survival after 8 years in the field was 50 percent and 10 percent. In the latter case, despite the extremely heavy loss, the remaining trees produced a very satisfactory growth, reaching on the average 8 feet in height and 1½ inches in diameter. This is probably due, at least in part, to better than average care; the trees are located on the farmstead and are a part of yard and orchard planting. In the third plantation, black walnut showed the highest loss (50 percent) among the hardwoods and the slowest rate of growth (height 4 feet; dbh ½ inch) of all plants in the windbreaks, even including red cedar. A small part of this plantation is on low land with poor drainage and occasional overflow after rain. In this part of the plantation black walnut survived better than red cedar, mulberry, and Chinese elm.

Catalpa.

Catalpa was represented in the present study by approximately 14,000 trees in 11 plantations. Survival of this species has been high—no less than 90 percent—although growth in some instances was not impressive. Only three plantations permit comparing the growth of catalpa with that of other

species. Eight others were pure fence post plantations. In one of the mixed plantations catalpa reached a height of 10 feet after 7 years (on a site of good quality) as compared to heights of 13 feet for green ash, 7 feet for black walnut and 20 feet for Chinese elm. In two other plantations (age unknown), catalpa was outgrown by Russian mulberry and Chinese elm, but taller than hackberry, osage orange, honey locust, or red cedar.

The plantations of pure catalpa which were studied varied in spacing from 3x6 feet to 6x14 feet, the majority being spaced 6x10 feet. Spacing, at least in the early stages, had no effect on survival. Under extremely variable conditions of soil, moisture and exposure as found in various plantations it would be impossible to tie growth statistically to any single factor responsible for the behavior of trees. Yet a study of tree size in relation to individual factors permits a few conclusions. Trees planted on higher ground are definitely smaller than trees of the same age set on lower ground. One plantation containing 4,000 trees is particularly illustrative in this respect. The average height of trees in the part of the plantations located on high ground was 10 feet (dbh=2 inches) while trees of the same age (9 years) but located in the lower part of the plantation have reached an average height of 18 feet. Another large 6 year old plantation (5,000 trees) presents a similar picture, individual trees varying in height from 7 to 18 feet, the size being strongly correlated with the elevation of the ground. The most impressive of the catalpa plantations visited by the writer was one planted in March, 1942 in which the trees spaced 6x10 feet have reached an average of 10 feet and dbh of 1½ inches with a total survival in 3 years of 98 percent. In all instances of good growth, plantations were located on light, well-drained soil, on relatively low ground.

Whether variation in spacing as observed in the plantations affects the rate of height growth is not entirely clear; all changes of spacing were connected with changes of the sites as well. It is interesting to note, however, that the tallest catalpa trees were spaced 3x10 feet and 3x6 feet.

The question of spacing brings up a problem of tree form which is of utmost importance in fence post production, for which catalpa is commonly grown. One of the striking characteristics of catalpa in all plantations was its tendency to branch and fork close to the ground and generally acquire a very crooked, unshapely form. A rapidly growing tree of such form may add much to its wood volume yet even in a long period provide relatively little material suitable for fence posts. Early pruning of such trees might be a possible solution in improving the quality of post material.

One notable exception to the generally crooked and limby trunks of young catalpa trees in inspected plantations were sprouts caused primarily by mechanical injuries. These grew as much as 8 to 10 feet in one year, forming straight, limb-free trunks. A possibility of producing first class fence post material by artificially induced sprouting needs a thorough investigation.

Chinese Elm.

Chinese elm is the most abundantly used species in forest plantations of north central Oklahoma. Of 28 plantations inspected in four north central counties, 19 originally contained Chinese elm. With the exception of one planting in which all trees of all species died soon after being planted (extreme drought), survival of Chinese elm was from fair to excellent. In 15 out of 19 plantations, survival figures are within the 90 percent to 100 percent range. The chief causes of mortality have been rodents and extreme cases of drought. In rate of growth, Chinese elm excelled all other species, reaching easily 20 feet in height at the age of 7 years. In some instances a height of 20 or more feet was attained after 5 or even 4

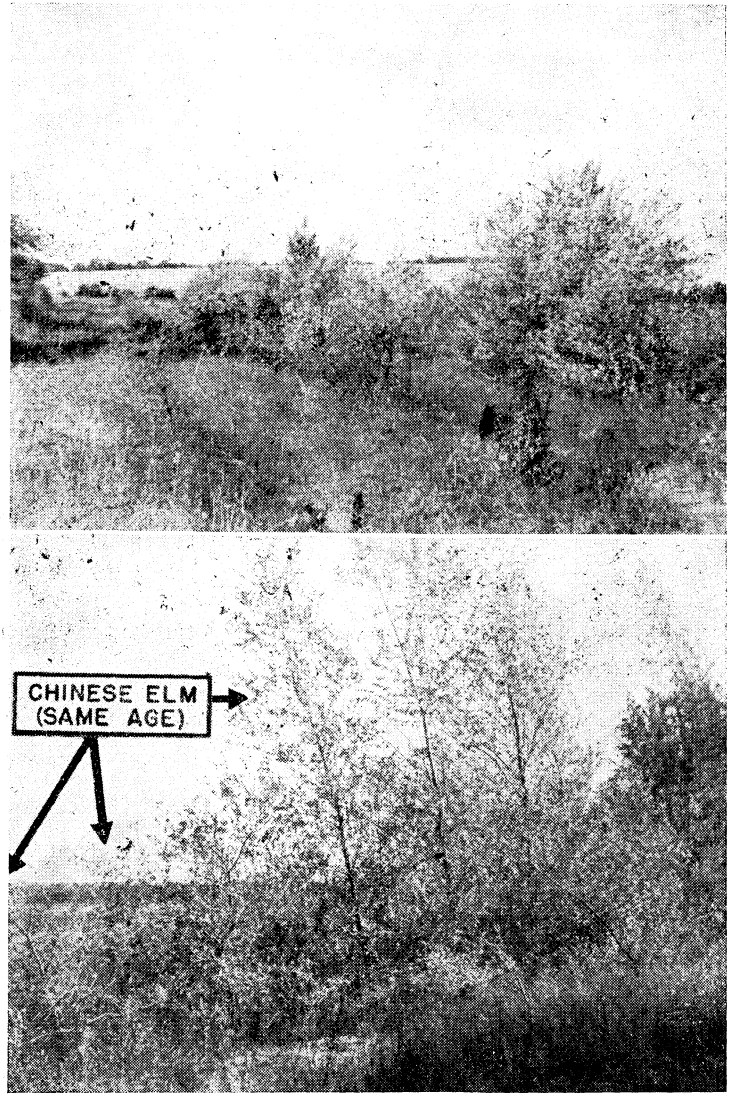

Fig. 4.—Variations in topography and exposure caused a generally spotty growth in this group of Chinese elm. Trees located in the lower spots outgrew more than twice those located on higher ground. Those on the higher ground were affected by sand blowing. Top: A general view of the location. Bottom: A closeup of one section.

years in the field. Relatively slow growth of Chinese elm in some plantations is associated with its high mortality as well as with reduced growth of other species, suggesting particularly unfavorable planting sites. In one of the instances, slow growth was due to a poor start under excessively dry conditions as well as to continuous exposure of trees to blowing sand. In another instance complete lack of protection from sand blowing, lack of moisture and very low fertility of soil (brought about by accumulation of sand) were causes of greatly reduced growth. Chinese elm grown on lower and more protected spots in the same plantation attained an average height of more than 20 feet in 5 years while trees located on the exposed and higher ground were less than 10 feet in height.

With a few exceptions Chinese elm is the first species in a mixed plantation to attain dominance and to provide protection to the adjacent area. In many instances it tends to outgrow other trees in height so rapidly, without affecting crown closure, that the plantation acquires a "fence-like" appearance. Because of the open spaces between fast-growing tops of Chinese elm, such plantations fail to provide as much protection as soon as would be the case if one more row of Chinese elm were added. By staggering Chinese elm in two rows, protection value of the windbreak can be greatly increased or brought about much earlier.

Among 19 plantations containing Chinese elm, three are pure. These are of particular interest because they may permit much more rapid accumulation of protective and material values. In general all three pure plantations of Chinese elm have been rather successful, although it is doubtful whether even under condition of dense planting the trees will produce material of high quality or suitable for anything but fuel. Lower limbs of Chinese elm persist under partial shade with little or no natural pruning taking place. The amount of fuel and degree of protection afforded by pure Chinese elm plantations rise rapidly from the time the trees are established.

Green Ash.

Green ash was encountered in only two plantations, one of which contained 200 and the other 150 trees of this species. Both plantations were located on low, reasonably fertile land. Survival of green ash in both was excellent—approximately 95 percent. It should be pointed out, however, that with exception of black walnut and hackberry, all other trees including even such exacting species as American elm had similarly small losses in these plantations. Growth of ash on both sites was good. In one case it reached a height of 13 feet in 7 years as compared to a height of 10 feet for catalpa in the same period of time. In the other case green ash grew to a height of 7 feet in four years as compared to a height of 15 feet of mulberry and honey locust, 6 feet of red cedar, 8 feet of American elm and 22 feet of Chinese elm.

Hackberry.

The weighted average survival of hackberry for 7 plantations (2490 trees) is 54.8 percent. Within the same plantations the average survival of other trees (pine excluded) was well above 90 percent. In rate of growth hackberry has also been inferior to other broadleaved species, with exception of black walnut and possibly osage orange. Hackberry and osage orange were found together in four plantations. In two of these the average height of hackberry was above that of osage orange (9 feet against 8 feet and 4 feet against 3 feet); in another the two species were of the same height; and in one instance osage orange was taller than hackberry. In comparison with other species hackberry is a slow grower. This, together

with high mortality in the field, makes it one of the least reliable species for forest planting in north central Oklahoma, with possible exception of unusually good sites.

In one of the best plantations visited, hackberry showed a good growth (7 feet in 3 years) though even under such conditions it survived to the extent of only 70 percent. When compared with other species on the same site it still fell into the class of slow growers. The following are the species and their heights on this four-year-old plantation: Chinese elm 22 feet, mulberry 15 feet, honey locust 15 feet, American elm 8 feet, hackberry and green ash 7 feet, and red cedar 6 feet.

Honey Locust.

Honey locust was found in four plantations, each containing from 50 to 350 plants of this species. In all four survival was excellent—from 95 to 100 percent. Association with many other species within these plantations provided a good basis for comparing honey locust with other commonly used trees. On good soil with adequate moisture supply (in one of the best plantations visited) it reached an average height of 15 feet and dbh of 2 inches after four years in the field. In this particular instance it was taller than red cedar, green ash, hackberry and American elm, being inferior in height only to black locust and Chinese elm and equal to mulberry. On a somewhat less favorable site (occasional low spots and standing water) honey locust grew to a height of 13 feet in 7 years. In this plantation it was next to Chinese elm in height and taller than mulberry, osage orange, and black walnut. The poorest growth of honey locust (4½ feet) was observed on a sandy, open ground in a poorly maintained shelterbelt estimated to be 3 years old at the time of inspection. However, here even Chinese elm and osage orange failed to develop properly, having reached a height of only 4½ feet. The tallest (6 feet high) in this plantation were catalpa and mulberry, the only two species which succeeded in forming a continuous canopy at a spacing of 6 feet.

Mulberry.

Mulberry has been located in 10 plantations, all windbreaks or field shelterbelts. An eleventh plantation originally containing this species was killed by a drought soon after it was planted. With this one exception, the survival of mulberry ranged from 90 to 100 percent, even on the poorest sites and in the poorly kept plantations. In its persistence mulberry ranks with the most dependable species such as osage orange and honey locust. It also ranks with the best species as to rate of growth, being outgrown only by Chinese elm and black and honey locusts. In the oldest of the inspected plantations (7 years of age) mulberry reached an average height of 12 feet as compared to 20 feet for Chinese elm, 13 feet for honey locust, 9 feet for osage orange, 5 feet for red cedar and 4½ feet for walnut. Under very favorable conditions mulberry grew to an average height of 15 feet in four years and to an average of twenty feet in 6 years, while Chinese elm (the fastest growing species) attained heights of 22 feet and 25 feet in the respective plantations. On poor sites mulberry is one of the most reliable species. In this connection one plantation is particularly illustrative. It is a 5 or 6 year old shelterbelt located on sandy infertile ground sloping to the north, in which Chinese elm and honey locust average 4½ feet in height. Mulberry on this site is 6 feet tall, the tallest species in the plantation.

Osage Orange.

With exception of one pure plantation which was killed by drought soon after it was planted in 1934, osage orange shows a rather high degree of survival (weighted average, 85 percent). Because of its tendency to bushy

growth, osage orange is one of the first species to form a continuous solid canopy in a closely spaced plantation. From that standpoint it is one of the most desirable species for use in windbreaks and shelterbelts. Its upward growth is slow when compared to that of some other species. The oldest planting of osage orange examined during the present study was in a windbreak containing in addition to osage orange, red cedar, mulberry, honey locust, Chinese elm, black walnut and desert willow. On this site there has been no loss of osage orange which in 7 years reached an average height of 9 feet. This height compares with 20 feet for Chinese elm, 13 feet for honey locust, 12 feet for mulberry, 5 feet for red cedar and 4½ feet for black walnut. This relationship in height holds more or less in other plantations with the exception of one in which growth of all plants was very poor. In this instance osage orange grew as well (or as poorly) as Chinese elm and honey locust. Generally, in regards to the rate of growth in height osage orange falls within the class of slow growers. Despite this unfavorable feature it still is one of the most desirable species and should be used widely in planting protective strips.

WESTERN OKLAHOMA (EXCLUSIVE OF PANHANDLE)

The western part of the state is characterized by low annual precipitation (20-28 inches), relatively light soils, and frequent strong dry winds. The region is a part of the so-called "Shelterbelt Zone." Consequently, some plantations established by the United States Forest Service were included in the present study. Mixed grasses, mesquite grassland, and shinnery oak grassland are the principal types of vegetation along the western border of the state. With exception of mesquite, tree growth (principally cottonwood and elms) is confined to banks of streams and rivers.

Red Cedar.

In the northern section of the western part of Oklahoma, red cedar was located in 10 out of a total of 21 plantations. In one of these it disappeared entirely, the loss attributed by the owner to dry weather which immediately followed the planting. The only surviving species in this plantation was osage orange (survival 95 percent), which reached a height of 4 feet in seven years.

Twenty-five percent survival of red cedar was recorded in another plantation as against 75 percent and 90 percent for black locust and mulberry respectively. Drought is considered by the owners to be the chief cause of high loss among the cedar. One other plantation has also suffered heavy loss in cedar (50 percent). This was due to the suppression of the cedar by the much faster growing broadleaf species (catalpa and Chinese elm) growing on both sides of the red cedar row.

In the remaining seven plantations, ranging in age from 3 to 8 years, the loss among red cedar did not exceed 10 percent, which compares favorably with the loss among such broadleaf species as black locust, honey locust, Chinese elm, and catalpa. In regard to the rate of height growth, red cedar stands near the bottom of the list, although in two instances it was taller than mulberry and osage orange on the same sites. Generally, the growth rate of red cedar in the northwest is slow. Average height of four-year-old trees was 4 feet, that of 8-year-old trees 7 feet.

In southwestern Oklahoma, red cedar was planted in nine of twenty inspected plantations. In the oldest of these 95 percent of red cedar still survived, having reached in ten years an average height of 10 feet and diameter of 3 inches. This plantation is located on silt loam and has been given excellent care.

Survival of more than 95 percent of red cedar was recorded also in two other plantations, both located on good well drained loam. Height of red cedar in both of these was equal to the number of years elapsed since the trees were set in the field (6 feet high in 6-year-old plantation and 7 feet in 7-year-old plantation).

Although in a few plantations the loss of red cedar was high, this loss could not be attributed entirely to a marked difference in adaptability between this and the broadleaved species, but rather to the poor quality site, on which broadleaved species suffered very high losses also. High mortality in one case was due primarily to characteristics of the soil (more than 40 percent clay at a depth of 15 inches) and at least in one case to the complete abandonment of cultivation.

Only in one instance did red cedar suffer relatively high loss (40 percent) when most of the broadleaf species did rather well. At the time of inspection this plantation was 9 years of age and located on sandy soil underlaid in places by tight blue clay at a depth of 17 to 20 inches.

With exception of black walnut, red cedar was found to be the slowest growing species in the southwest. Even trees planted for ornamental purposes and receiving good individual care have been growing in height but one foot annually.

Pine.

Only two plantations inspected in southwestern Oklahoma contained pine. In both, the pines (Austrian and western yellow) were practically gone at the time of examination. The older of the two, planted March 11, 1933, had only 6 pine trees left of a total of 200. Three of these were dying. This planting has been receiving better than average care. In the other plantation, less than one-half of one percent of pines are still living.

American Elm.

American elm has been found in one plantation only, and therefore no conclusive statement concerning its adaptability in forest plantations of northwestern Oklahoma can be made. In this instance only a few American elms were still living, while the average survival of other species in the same shelterbelt was approximately 95 percent.

Black Locust.

In northwestern Oklahoma, black locust was located in 7 out of 21 inspected plantations. The lowest survival of this species (60 percent) was observed in a pure plantation on relatively low and fertile ground. High mortality in this instance can be attributed to very close original spacing (6 feet x 6 feet) and failure to thin the plantation when serious competition for space developed. As a result of this strong competition the weaker trees became suppressed and died. The high quality of this site can be seen from the fact that the stronger, faster growing trees which succeeded in attaining dominant positions are 20 to 25 feet tall and up to 3 inches in dbh after 7 years in the field.

The average survival of black locust in the northwest is high (88 percent) and in the rate of growth this species is outdone only by Chinese elm and cottonwood. After 4 years in the field black locust has reached an average height of 8 feet, and after 7 years, 17 feet.

In shelterbelts of southwestern Oklahoma, black locust was observed in 6 instances. One post plantation containing this species was also examined. Black locust has done very well in all but one plantation. In the latter case all other species also show very high mortality (see photo page 8), the cause of the latter being a very shallow layer of tight top soil under-

laid by blue impermeable clay subsoil. In other plantations, black locust has done as well as, or better than, all other species associated with it on the same sites. In the inspected plantations established since 1938, average survival of black locust has been 96 percent. In the oldest plantation visited and containing this species (1936), 80 percent of black locust are still living. All plantations in which high survival of black locust was noted are located on sandy soils. The limited number of plantations does not permit reliable conclusions as to effect of poor drainage on the behavior of black locust, though it is safe to assume that excessively heavy soil would be detrimental to the development of this species.

In rate of growth, black locust stands close to the top of the list, being inferior only to cottonwood and Chinese elm. The average height of this species on better sites is 18 to 20 feet at the age of 7 years. The average diameter at the same age is 3 inches.

Black locust is the first of the observed species to reproduce itself, chiefly by means of suckers. In older plantations, space vacated by the loss of other trees is being taken over by black locust.

No cutting of black locust has been observed. Spaced in most instances 8 feet x 10 feet, black locust often forks close to the ground, suggesting a need of early pruning where post production is the principal aim.

Black Walnut.

In northwestern Oklahoma, this species was located in only one plantation, which was established in 1941. The survival of various species in this plantation has been the exact opposite of those in the great majority of plantations in this state. Black walnut and red cedar, normally showing the heaviest loss, survived to the extent of 90 percent, whereas the survival of other species was between 40 percent (mulberry) and 85 percent (black and honey locusts). Even here, however, the growth rate of black walnut was extremely slow. This species reached a height of only 2 feet after four years in the field.

Of four inspected plantations in southwestern Oklahoma originally containing black walnut, two have lost this species altogether, yet survival of eight other species was very high (90 percent or better), suggesting the exacting nature of black walnut and probably its intolerance of heavy competition in mixed plantations. The soil in both plantations is at least fair and well drained. Heights of trees other than black walnut ranged from 15 feet (mulberry, green ash and hackberry) to 25 feet (cottonwood) in one 6-year-old plantation, and from 4 feet (red cedar) to 15 feet (Chinese elm) in another (four years old).

The only plantation still containing 95 percent of originally planted black walnut (1938) is located on good loam soil, and all species composing the plantation are in a better than average shape. Even under these conditions black walnut reached in 7 years an average height of only 4 feet, as against 7 feet for the "slow growing" red cedar.

Catalpa.

Catalpa was located in two plantations in the northwestern part of the state. In both instances, the survival was high, 90 percent and 95 percent; yet in rate of growth catalpa has been among the slower growing species on the same sites. After 5 and 8 years in the field, average heights of the trees were 6 and 8 feet respectively. On the same sites, honey and black locust were twice as high and Chinese elm, 2½ times as high as catalpa.

Catalpa has been encountered also in six southwestern shelterbelts in association with other species, all on sandy soils.

With exception of one plantation in Greer County, in which 50 percent of catalpa were lost, all others show a high degree of survival of this species—90 percent or better. In the Greer County plantation the cause of the high loss is not quite clear. It is one of the thriftiest shelterbelts inspected in which 95 percent of all other species, even including black walnut, are still alive and growing exceptionally well. One possible reason for the high loss of catalpa might have been its destruction by rabbits. In this particular plantation, catalpa reached in 7 years a height of 7 feet and a diameter of 2 inches. It was shorter than any other species, excepting red cedar (7 feet) and black walnut (4 feet).

In all other plantations, catalpa was exceeded in rate of growth only by cottonwood, Chinese elm, and black and honey locusts. Its vigor generally was excellent.

Chinese Elm.

In northwestern Oklahoma, Chinese elm, according to field observations, is third among the species in the number of trees planted. Generally, it has been doing well both in regard to survival and growth. With exception of two shelterbelts (out of a total of 13) survival of Chinese elm has been more than 90 percent even under conditions of poor exposed sites, and without much (or any) care from the owners. The relatively low survival—60 percent and 70 percent—and poor growth of Chinese elm (4 feet tall in 8 and 4 years respectively) are associated with southern exposure, poor sandy soil, and complete lack of care of the plantation. In both of these shelterbelts, Chinese elm has been doing worse than black and honey locusts, osage orange and green ash; and in one of them, even worse than red cedar and black walnut.

In the remaining 11 plantations, ranging in age from 4 to 11 years, Chinese elm has done very well in respect to both survival and growth. Average survival was 95 percent and height of trees ranged from 10 to 25 feet.

In southwest Oklahoma, Chinese elm has been used in more plantations and in larger numbers than any other tree. In general, survival of this species is very high. Two of the oldest plantations visited (one planted in 1932 and the other in 1935) still contain 80 and 60 percent of the originally planted Chinese elm. Loss suffered by these two plantations is attributed by their owners to severe droughts in the middle 1930's.

Of 24 plantations listed as having originally contained Chinese elm, three do not have this species now. Due to changes in ownership, no reason for this loss has been determined. Of the other 21, there has been a heavy loss of Chinese elm in three plantations: one lost more than 90 percent of its Chinese elm because of extremely heavy soil, livestock damage, and lack of care; one suffered a loss of 90 percent because of shallow, very heavy soil, on which survival of other trees was also very low; and one lost 50 percent, the loss attributed by the owner to severe unseasonal freezing. In the latter case, many trees died not during the first season, but during 1944, after reaching heights of 10 to 12 feet. Dying of large, apparently well established Chinese elm, was found to be not uncommon in the southwest. Whether this is a result of an unseasonal hard freeze in the fall of 1940, soil conditions, or a disease has not been determined.

In 19 out of 24 plantations, survival of Chinese elm has been 80 percent or higher and in 13 plantations, 90 percent or more of the Chinese elms have still been living. Although soil texture is a governing factor in the survival of trees, it alone cannot be responsible for variations in the mortality of Chinese elm. Some of the high losses indicated above appear to have

TABLE III.—Average Size of Chinese Elm at Various Ages.

No. of years in the field	Av. height (feet)	Av. diameter (inches)
5	10	2
6	16	3
7	25	5
8	20	4
9	23	5
13	25	5
14	20	

been caused by very heavy soil, yet in other instances, as many as 95 percent of Chinese elms have survived for 8 years on very heavy soil, attaining an average height of 25 feet and a diameter of 6 inches.

With the possible exception of cottonwood, Chinese elm grew faster than any other species. Table III represents approximate average heights and diameters of Chinese elm at various ages as found in the inspected plantations of the southwest.

Lack of correlation between age and dimensions of Chinese elm trees is due to a very limited representation. However, even these figures provide an overall picture of the average rates of growth of Chinese elm in plantations of southwestern Oklahoma. The species grows rapidly when very young but slows in growth very markedly after reaching 8 to 12 years of age. Judging by behavior of individual trees located in the open (shade and street trees), which continue to grow rapidly in diameter after the age of 10 years, it is reasonable to assume that marked reduction of growth in a plantation is due to limitations of the site's potential productivity. Very heavy thinning of a stagnant plantation at that age may or may not result in the renewal of diameter growth. Original spacing of Chinese elm, ranging from 4 feet x 10 feet to 15 x 30 feet, appears to have had no marked effect either on the survival or the initial rate of growth (in 9 years of this species.

If it were not for the dying of relatively large trees, the cause of which is not known, Chinese elm would be one of the most dependable species for southwestern Oklahoma, particularly if a rapid protective effect is desired.

Silvicultural limitations of this species are not greater than those of other species used for afforestation in the southwest. On sites failing to support Chinese elm, very few if any other species can be expected to grow satisfactorily.

Cottonwood.

Survival of cottonwood in plantations of northwestern Oklahoma has been from poor (5 percent) to excellent (95 percent). In most instances, cottonwood lost from 20 to 30 percent of the original number of trees, which put it in regard to survival below most other species found in the same plantations.

As should have been expected, it survived best on lower ground with at least a fair supply of moisture and with relatively wide spacing (10 feet x 12 feet). On higher ground the loss of cottonwood has been very severe; in some instances, it disappeared altogether, on dry exposed sites.

The average height of this species is 15 to 16 feet after 7 years in the field. On better sites it attained a height of 25 feet in the same number of years. In rate of growth cottonwood stands among the fastest growing species.

All cottonwood inspected in southwestern Oklahoma was found in 6 shelterbelts planted by the United States Forest Service. All were located on sandy soil. The lowest survival of this species (70 percent) was recorded on land on which signs of fire damage and lack of cultivation suggests these as possible causes of a relatively high mortality. Mortality of 25 percent was noted in one other shelterbelt. Survival in the remaining four was was more than 90 percent.

In seven years cottonwood reached an average height of 22 feet and a diameter of 4 inches. Individual trees have attained in 7 years a height of 30 feet and a diameter of 8 inches.

From the standpoint of protection, cottonwood, on the record of its performance, is one of the most desirable species for the southwestern counties.

Green Ash.

In no region of the state has green ash survived as well as in the northwestern part of Oklahoma, particularly if compared with other species found within the same plantations. In one of the 10 plantations containing green ash, survival of the latter was 70 percent, in two others, 85 percent, and in the remaining 7 plantations, 90 percent or better. Even with a survival of only 70 percent, green ash made a good showing—the entire plantation was very poor; only honey locust and osage orange survived somewhat better (80 percent) than green ash. Under the same conditions, survival of Chinese elm was 40 percent, that among cottonwood 95 percent, and two rows of trees (species unknown) disappeared altogether. Excluding the poorest of the plantations (in which the loss of green ash was 30 percent), growth of green ash has also been very satisfactory, the trees ranging in height from 5 to 12 feet after 5 to 8 years in the field. Green ash has made a relatively better showing in the west than it did in the north central part of the state.

In the southwest, no trace of green ash has been found in two plantations which originally contained that species. Of five other plantations, four still have more than 90 percent of the original green ash, while in the fifth, the loss among this species was 70 percent. In the latter case, the loss of ash was 60 percent, even in that part of the plantation which adjoins a creek and on which other species (Chinese elm, honey locust, and mulberry) have hardly lost any of the originally planted trees. The high loss of green ash on the good site can probably be attributed to its extreme intolerance of shade. It was outgrown and shaded by all other species found in the plantation.

In all cases of high survival, plantations were located on light and apparently fairly fertile soils where other trees grew as well as, or better than green ash. No green ash was found in any of the plantations located on heavier soils, and consequently the effect of such soils on this species has not been observed.

The rate of growth (height) of green ash has been considerably faster than that of black walnut, somewhat faster than that of osage orange, hackberry, and red cedar, but slower than growth of Chinese elm, honey locust, black locust, catalpa, and American elm. The fastest growing trees of green ash attained a height of 15 feet and diameter of 2 inches in 7 years. It should be added, however, that on this site, all other trees are either of that size (mulberry, hackberry) or larger (black locust, honey locust, catalpa, and cottonwood).

Hackberry.

Of four plantations in northwest Oklahoma originally containing hackberry, only one still bears a satisfactory growth of this species. This plantation, a Forest Service shelterbelt established in 1937, receives excellent care, and with the exception of hackberry no species in it sustained a loss greater than 10 percent. Survival of hackberry is 85 percent. Its average height is 18 feet and average dbh 2½ inches.

Of three other plantations, two lost hackberry completely and in the third, survival of that species was only 30 percent. As in the rest of the state, hackberry stands at the bottom of the list in regard to its performance in mixed plantations.

Excluding one plantation in which all species have done very poorly, survival of hackberry in the southwest ranged from 70 to more than 95 percent. The oldest of the examined plantations containing hackberry was 9 years old. The average height of hackberry in this plantation was 8 feet and the average diameter 1½ inches. In four other plantations the height of 8 feet was reached after 7 years in the field. In relation to other species, it is a slow grower and in this respect is second from the bottom on the list of broadleaved trees.

Honey Locust.

The average survival of honey locust in all inspected plantations in the northwest part of the state is 83 percent, with 10 plantations showing survival of 90 percent or better. The highest loss (40 percent) was found in 3 shelterbelts in 2 of which survival of most other species has been poor also (osage orange 5 percent-60 percent; mulberry 50 percent; hackberry 30 percent). In other words, high mortality in these instances should be attributed to generally unfavorable sites rather than to a smaller degree of adaptability of honey locust in comparison with other species. On sites where other species do reasonably well honey locust has done as well or better. In rate of growth honey locust stands fourth among all other species planted in the northwest, being inferior in this respect only to cottonwood, Chinese elm, and black locust. Considering the desirable qualities of its wood, honey locust remains one of the most valuable species in the northwest. The only serious objection to its use is a high proportion of thorny specimens which make any work within the plantation rather difficult.

The relatively slow growth of honey locust on some sites is closely correlated with high mortality of this species, suggesting a set of unfavorable growing conditions. The slowest growth of honey locust observed in the field was 8 feet in 9 years (survival 60 percent). However, for the entire northwest the average height of 8 feet has been reached by honey locust in 4 years and trees after 8 years in the field have an average height of 17 feet. On the best sites and with good care, individual trees of honey locust reached a height of 25 feet and dbh of 4 and 5 inches at the age of 6 years.

In the southwest honey locust has been found in 16 plantations. Although mortality of this species in a few instances has been high, only in one case does honey locust compare unfavorably with other trees found in the same plantation. Here the loss of honey locust was 80 percent as compared with a combined average loss of 28 percent for 5 other species on the same site. In rate of growth it has been exceeded by cottonwood, black locust, and mulberry. Only osage orange has been doing as poorly as honey locust in the same plantation. Since both honey locust and osage

orange were growing in the adjacent rows (first and second), it is possible that variations in soil and drainage may have been responsible for the abnormally poor showing of these two species.

High mortality (50 percent) of honey locust in another plantation has been caused by a shallow layer of fairly heavy soil, underlaid with heavy blue clay on which all other trees have also suffered unusually heavy losses. Mortality of trees in 6 years ranged from 90 percent for Chinese elm to 40 percent for red cedar and black locust and the trees of all species continue to die every year. The tallest trees in the planting were about five feet in height. Complete failure of this plantation is undoubtedly due to the character of the soil. Analysis of the soil indicates the following fractions: 26 percent sand; 36.2 percent silt and 37.8 percent clay. Part of the same plantation is doing extremely well. Here the content of clay is 22 percent and that of sand and silt 16 percent and 62 percent respectively. (See photo, page 8).

Outside of the two plantations discussed above, honey locust is doing very well in thee southwestern part of the state. Its survival ranges from 80 to more than 95 percent and in rate of growth it stands next to cottonwood, Chinese elm and black locust. It does not make a "large" tree, though individual trees are as tall as 25 and 28 feet. The average height of honey locust in 7 years is about 12 feet and the average diameter at the same age 2 inches.

Mulberry.

With two exceptions, survival of mulberry in the northwestern counties of Oklahoma has been high (average for 11 plantations, 91 percent). In one instance, low survival (40 percent) was probably due to grazing. Mulberry in this instance forms the first row of a shelterbelt adjacent to an open pasture. Failure of this row to grow in height (1 foot in 4 years) is due to the same cause or, indirectly, to the owner's failure to fence off the plantation.

Another partial failure of mulberry (survival 50 percent) has been due to an extremely poor site (blowing sand, exposure to strong southern wind, erosion) on which five other species have suffered high losses also.

In rate of growth mulberry can be compared with osage orange, being a rather slow grower in height but spreading sidewise and closing crowns rapidly. Also like osage orange, it can hardly be counted upon to produce good fence post material unless thinned and pruned.

Excluding the two particularly unfavorably situated plantations described above, the approximate average heights of mulberry bushes in the northwest are 5 feet after 4 years and 12 feet after 8 years in the field.

Mulberry has been used rather extensively in forest plantations in southwestern Oklahoma. It was located in 9 shelterbelts. Two other plantations were also listed as originally containing this species.

Loss among mulberry in the southwest has generally been rather high, yet in three plantations more than 95 percent of the originally planted trees of this species are still living. In the others the loss of mulberry has been from 40 percent to 60 percent. With the exception of one instance in which 98 percent of the osage orange have survived while only 50 percent of mulberry are still alive, survival of the two is somewhat similar when both are located in the same plantation.

On better sites, mulberry reached a height of 12 feet in 7 years; on poor sites, associated with high mortality, its growth has been restricted to from 3 to 6 feet in the same period of time.

Osage Orange.

Excluding one plantation in which mortality of all species was very high, the average survival in 13 plantations was 88 percent. Typical of the osage orange is its tendency to form many-stemmed plants, which forces an early crown closure and makes it one of the most desirable species from the standpoint of wind protection. Although height of osage orange is not the sole indication of the vigor of its growth, it is of considerable importance because of its effect on wind velocity. In most cases osage orange has been among the slower growing trees (in height), yet on good sites and with good care it almost reached the average height of the entire shelterbelts. In one instance it grew to a height of 18 feet in 9 years as compared to 20 feet for Chinese elm, 25 feet for honey locust and 18 feet for black locust. On the average, however, the upward growth of osage orange is much slower. The average height after 5, 7 and 9 years in the field have been 5½, 9 and 11 feet respectively.

The performance of osage orange in the southwestern part of the state is rather variable. In one plantation in Kiowa County, every osage orange plant was lost due to extremely heavy soil and, probably, lack of care. Six miles east of this plantation, in two plantations located on good wheat land, osage orange planted in 1933 and 1935 survived to the extent of 98 and 90 percent respectively, despite the severe droughts of the middle 1930's. Trees at the time of inspection (February 1945) were 15 and 18 feet tall with an average diameter of 2½ inches. Besides being located on good sites, these plantations have been given excellent care. Early removal of all but one stem per plant and pruning resulted in a stand of straight, rapidly growing trees with clean trunks up to a height of 8 or 10 feet. The trees were spaced 6 feet x 6 feet.

Survival of 90 percent and more was recorded in a total of seven out of 19 plantations. All seven were on well drained soil. The latter is not necessarily an assurance, however, against high mortality. In two plantations located on light soil, osage orange lost 30 to 35 percent after four and six years in the field respectively. It is entirely possible that in these instances sandy soils were underlaid with heavy impermeable susboil, a situation not uncommon in southwestern Oklahoma. The highest losses of osage orange (from 80 to 100 percent) were noted in plantations located on very heavy shallow soils (with heavy blue clay subsoil in one case) where other trees have lost heavily also.

In rate of growth (height) osage orange stands above walnut, hackberry and the conifers, and below black locust, cottonwood, Chinese elm, honey locust, green ash, and catalpa. On a fairly good, well drained soil, it attained an average height of 10 feet in six years.

With the exception of two instances described at the beginning of this section, no improvement cutting of any type has been applied to osage orange. The natural growth habit of this species tends to produce a bushy, wide-spreading plant, which can not be expected to yield post material for a long time to come. Excellent results in two thinned and pruned plantations clearly indicate this to be the proper handling of osage orange for production of fence posts.

EASTERN OKLAHOMA

The eastern section of the state forms a part of the so-called Central Hardwood Forest and contains a large amount of broadleaf species well adapted to the region. It is a natural habitat of forest trees and therefore presents fewer difficulties in regard to planting and growing of trees than any other part of the state. It receives an average of approximately

40 inches of annual precipitation and seldom suffers from prolonged damaging droughts. The soils range from poor rocky and gravelly in the southeast to deep dark soils of fair fertility in the northeast.

Because of the existing large natural stands, forest tree planting in eastern Oklahoma has beeen confined chiefly to the production of fence post material. Shelterbelts and windbreaks are the exception rather than the rule. Consequently, although many species have been planted, only catalpa and black locust are found in large numbers in forest plantations of the eastern part of the state.

Red Cedar.

Red cedar was located in only two plantations, although three more inspected plantations originally contained some red cedar. In other words, three out of five plantings of red cedar were complete failures. In the fourth the 3 year mortality of cedar was 75 percent, and surviving trees made extremely poor growth, reaching an average height of 2½ feet. Only one of the inspected plantations showed a high survival (more than 90 percent). This plantation is of pure cedar, well kept, and contains trees of apparently good health and vigor.

Black Locust.

Black locust was located in 18 of a total of 24 inspected plantations. This species is by far the most popular and widely planted in northeastern Oklahoma. Eleven out of 18 plantations were pure, the other seven containing from one to four species other than black locust. Of 18 plantations inspected, two were complete failures. One of these is located on a slag ridge, where 5 percent of trees survived in 5 years. The other is found on a site which has failed to support catalpa and mulberry as well. Poor, shallow soil, together with late planting, appear to be the chief causes of failure in the latter case.

One other plantation has suffered high mortality (50 percent) among black locust trees; this was planted in Spring, 1942, on ground with western exposure and, judging by its appearance, received no care or protection.

In the remaining 15 plantations, ranging in age from 3 to 8 years, survival of black locust was more than 90 percent, although the rate of growth and the general vigor of the trees were not uniformly good in all instances. The trees vary considerably in size even within individual plantations, suggesting the exacting nature of black locust regarding quality of the site—especially in texture, depth and reaction of the soil—and probably a high degree of intolerance. On better sites black locust reached an average height of 15 to 20 feet and dbh of 2½ inches in 5 years; on poorer sites it grew to a height of 5 to 8 feet in the same period of time. In total, there are more "good" black locust plantations than "poor" ones.

In mixed plantations, black locust is tallest of all the species planted, being approached in size on better sites only by catalpa.

Failure on the part of the owners to prune black locust resulted in heavy branching and forking of trees with subsequent failure to produce first grade post material. Careful pruning and generally thorough care of the plantation were observed in only one instance.

Black Walnut.

Black walnut was found in one plantation. Two others visited in the course of this study had lost all trees of this species. Even in the former only one percent of trees originally set were still living. These trees were planted in Spring, 1941, on extremely poor shallow soil. The plantation did not appear to be cared for, and black walnut showed no sign of growth since the time of planting. Average height of the trees was one foot.

The complete loss of black walnut in two other plantations was probably caused by severe droughts immediately following planting. One of these plantations was started in 1933, the other in 1936.

Catalpa.

In regard to the number of trees planted in the east, catalpa stands second from the top of the list. Of 23 plantations examined, 14 contained this species. In only two instances have the survival and growth of catalpa been unsatisfactory. In all other plantations more than 90 percent of the planted trees were still living at the time of inspection. The vigor of catalpa was from fair to excellent.

The failure of catalpa in the two plantations mentioned above was caused by extremely poor shallow soil on which other species less exacting in soil requirements, such as mulberry and black locust, also have suffered high losses.

Due to a relatively high annual precipitation and at least a fair soil used for the plantations, catalpa has done well even on the uplands, although the very best plantations of this species were found along the creeks and on low ground.

The largest trees of catalpa reached a height of more than 20 feet and a diameter of 3 inches after 5 years in the field. This plantation had been receiving unusually good care which included cultivation and pruning.

The average height of catalpa after 4 years in the field was 7 feet and after 5 years 11 feet. Trees of the two ages are not comparable due to the differences in site quality.

Most of the catalpa plantations in eastern Oklahoma are pure, allowing no comparison with other species on the same sites.

In a few plantations containing other species besides catalpa, the latter outgrew mulberry and Chinese elm, but was considerably shorter than black locust.

Generally, in the northeastern plantations, catalpa has done better than any other species with the exception of black locust. From the standpoint of fence post production it compares favorably even with the black locust. Left alone, as most trees are in farm plantations, catalpa produces somewhat better form than black locust. Having a considerably smaller proportion of sapwood, it should not take any longer than black locust to produce material of fence post size.

Chinese Elm.

Contrary to its behavior in the central and western parts of the state, Chinese elm has made a rather poor showing in eastern Oklahoma. In only one instance out of 4 did this species survive to the extent of more than 90 percent and appear to have fair vigor. Even here it grew in 3 years to a height of 5 feet since the time it was set in the field in Spring, 1942. In the other plantations survival of Chinese elm was 50 percent, 10 percent, and less than 5 percent. In the last instance planting was done 13 years ago and at the present time the place is completely abandoned.

Green Ash.

Green ash has been located in one plantation where, as compared to other species, it made an excellent showing. Ninety-five percent of trees of this species were still alive after 4 years in the field. The average height of these trees was 8 feet, equal to that of catalpa in the same plantation and better than that of osage orange, mulberry, or Chinese elm.

Mulberry.

Mulberry, found in 6 plantations ranging from 3 to 6 years in age, survived to the extent of more than 90 percent, with one exception. In the latter instance, trees of all species planted on the same site have been lost. The owner attributes the complete loss of trees to late planting, but the examination of the site revealed also the extremely poor quality of shallow soil which undoubtedly contributed greatly to the failure of planting. In two plantations growth of mulberry has been better than satisfactory. In rate of growth it generally stands below black locust, green ash and catalpa, but above osage orange, Chinese elm, and the conifers. In the remaining 3 plantations, mulberry reached an average height of only 3½ feet in 4 years.

Mulberry has less value as a source of fence post material than either catalpa or black locust. It is subject to frequent frost injury in late spring (killing back of the tips) and often is bushy in form.

Osage Orange.

Osage orange has been located in two plantations. Survival is high in both (95 percent) but growth has been extremely slow. Osage orange after 4 years in the field was but 4 feet tall, while 3 year old trees were only 3 feet tall. In both instances osage orange trees were the smallest in the plantations, being exceeded in growth by Chinese elm, green ash, catalpa, mulberry, and black locust.